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Trends in phytoplanktonic and zoobenthic communities after the decrease of phosphorus concentrations in Lake Joux

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Trends in phytoplanktonic and zoobenthic communities after the decrease of phosphorus concentrations in Lake Joux. – The eutrophic Lake Joux (Jura Mts., Switzerland) has been continuously colonized from 1980 to 1992 by dense populations of *Oscillatoria rubescens*, even after phosphorus concentrations began to decrease in 1986. At a depth of 25 m, biomass and abundance of chironomid larvae decreased between 1985 and 1992 whereas abundance of *Chaoborus* larvae increased. In addition, abundance of *Tubifex tubifex* increased in tubificid communities relatively to that of *Limnodrilus hoffmeisteri*. These trends are indicative of a deterioration of oxygen conditions in the profundal. They suggest that benthic communities will not recover from eutrophication as long as planktonic communities are dominated by *Oscillatoria*.

Key-words: Benthos - Bloom - Cyanobacteria - Eutrophication - Oligochaeta.

INTRODUCTION

In Lake Joux (Switzerland, Vaud, Jura Mts., alt. 1008 m), blooms of *Oscillatoria rubescens* DC were recorded for the first time in 1972 (Bosset 1981). Since 1980, this species dominated the phytoplankton in terms of biomass. Its expansion was facilitated by the increase of total phosphorus concentrations from 25 mg·m^{-3} in 1980 to 45 mg·m^{-3} in 1985 (Vioget 1991). Accordingly, Lake Joux was classified as eutrophic in 1982 (De Heer 1984); and, at the summer end, the profundal was anoxic below 15 m down to 30 m, the maximum depth. As a consequence, the profundal was colonized only by zoobenthic species adapted to the extreme conditions of eutrophic lakes (Lang & Lang 1986).

However, phosphorus concentrations began to decrease in 1986 from the maximal of 45 mg·m^{-3} in 1985 down to 25 mg·m^{-3} in 1990 (Vioget 1991). In the present study, we examine the effects of this reversal of eutrophication on phytoplanktonic and zoobenthic communities. And we ask two related questions: 1. Is there any downward trend in the abundance of *Oscillatoria*? 2. Is there any changes in zoobenthos which are indicative of improved conditions in the profundal?

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These two questions are related because benthic communities respond directly to organic sedimentation derived from phytoplankton (LANG & HUTTER 1981), especially if the sedimented matter consist mainly of *Oscillatoria* threads (HUTTER & LANG 1981). Hence, it is probable that zoobenthic communities will not recover from eutrophication as long as planktonic communities are dominated by *Oscillatoria*.

STATIONS AND METHODS

Phytoplankton was sampled from 1980 to 1992 at one site located in front of Pont village. Samples were collected every two weeks, from April to December, by lowering vertically a weighted tube from the surface to a depth of 10 m. Algae, present in this integrated sample, were identified and counted under an inverted microscope. Dimensions of algae were used to compute their volume which was converted into biomass (wet weight).

Zoobenthos was sampled from the same site as phytoplankton, but at a depth of 25 m. From 1985 to 1992, ten 16 cm^2 cores were collected by a diver in April, June, and October of each year. The sediment collected in each core was sieved (mesh size aperture: 0.2 mm) and the retained material was preserved in 5% formalin. Tubificid worms, chironomid and *Chaoborus* larvae were counted and weighed after removing excess water with blotting paper.

The Cox and Stuart test for trend (CONOVER 1971, p. 170) was used to detect downward trends in median abundance of *Oscillatoria* between years (Fig. 1). Years were divided into two groups of six years each: 1980/85 and 1987/92, the middle year, 1986, was omitted. Then, the years which occupied the same position in each group were paired to compute the T statistic. To detect trends in zoobenthic data (Tab. 1), the Spearman rank correlation was computed by pairing mean abundance or biomass of zoobenthos with the time at which the measurements were taken (CONOVER 1971, p. 251).

RESULTS

PHYTOPLANKTON

Oscillatoria rubescens DC and/or *O. agardhii* Gom. (identified by M.E. Meffert, Plön, BRD) were present in each of the 283 samples collected in Lake Joux between 1980 and 1992. In most cases, these two species formed the main part of the phytoplanktonic biomass.

Figure 1 showed that median biomass of *Oscillatoria* per year decreased from 1980 to 1983, increased from 1983 to 1988, and decreased from 1988 to 1992. However, these graphical trends were not confirmed by statistical analysis which indicated no significant downward trend if the 1980/85 years were compared with the 1987/92 years (Cox and Stuart test for trend, T=5, n=6, p=0.984, see Stations and methods).

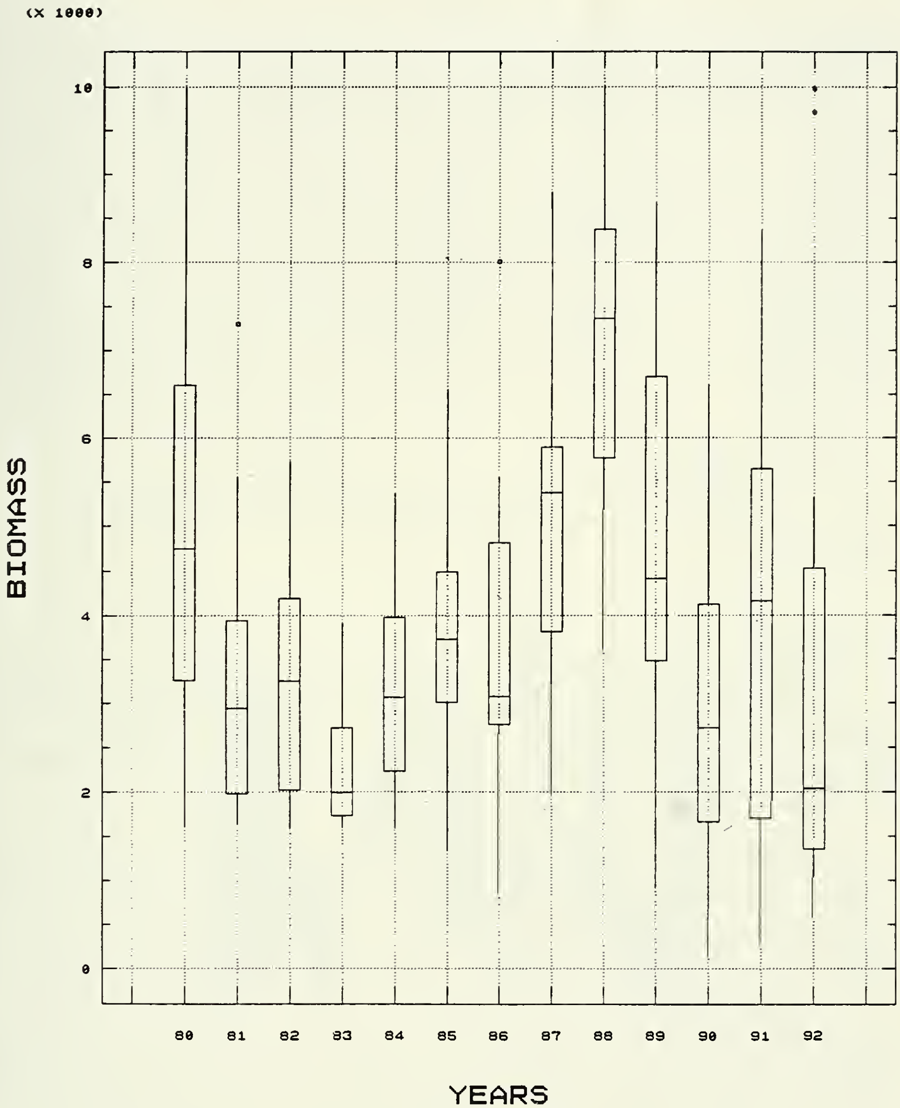

FIG. 1

Variations of median biomass (mg·m^{-3}) of *Oscillatoria* per year from 1980 to 1992 in Lake Joux. The central box covers the middle 50% of the values, bars extend to the extreme, outliers are shown as single dots.

TABLE 1

Mean biomass (B) and abundance (A) of zoobenthic taxa in Lake Joux: comparison between the 1985/88 years and the 1989/92 years, based on 120 cores in each set. The 1985/92 trend is assessed with the Spearman rank coefficient (see Stations and methods, n=24).

	Taxa	Unit	Trend r_s (probability)	Mean 1985/88	Mean 1989/92	Test	Probability
B	All	mg $\cdot 16 cm^{-2}$	–0.31 (0.135)	90.3	76.2	Mann-Whitney	0.004
	Tubificids		0.06 (0.761)	43.2	42.7		0.736
	Chironomids		–0.64 (0.002)	39.9	15.1		0.039
	Chaoborus		0.34 (0.122)	7.1	18.4		0.298
A	Tubificids	no $\cdot 16 cm^{-2}$	0.11 (0.593)	67.2	69.3		0.308
	Chironomids		–0.73 (0.000)	4.6	1.5	Median	0.000
	(if present)		–	4.7	2.4		0.000
	Chaoborus		0.05 (0.825)	1.8	4.1		0.142
	(if present)		–	3.3	6.8		0.000
	Limnodrilus hoffmeisteri (%)		–	76.2	36.4	Chi^2	0.000*
	Tubifex tubifex (%)		–	23.8	63.6		

* Based respectively on 143 worms collected in 1985 and on 55 worms collected in 1992.
– not computed.

ZOOBENTHOS

Zoobenthic taxa, present in Lake Joux at a depth of 25 m (Tab. 1), were ranked according to their increasing resistance to severe anoxia: chironomid larvae, tubificid worms (*Limnodrilus hoffmeisteri*, then *Tubifex tubifex*), and *Chaoborus* larvae (BRINKHURST 1974). This rating was used to assess the significance of trends recorded between 1985 and 1992.

Biomass of *Oscillatoria* did not decrease between 1980 and 1992: therefore, we can assume that the less resistant zoobenthic taxa (chironomids) will decrease whereas the most resistant taxa (*Chaoborus*) will increase. Indeed, chironomid larvae decreased whereas *Chaoborus* larvae increased (Tab. 1, Fig. 2). In addition, abundance of *Tubifex tubifex* increased in tubificid communities relatively to that of *Limnodrilus hoffmeisteri*.

The downward trend for total biomass was not significant (Tab. 1), because of the increasing contribution of *Chaoborus* (Fig. 2). Indeed, the downward trend became significant (r_s=-0.45, n=23, p=0.031) if the sample collected in June 1992 was eliminated. In this sample, *Chaoborus* contributed heavily (68%) to total biomass. Biomass of tubificids pooled with that of chironomids decreased significantly between 1985 and 1992 (r_s=-0.64, n=24, p=0.001). In other words, zoobenthic taxa which, contrary to *Chaoborus*, were unable to migrate every day into the oxic layers, were especially affected by anoxia.

All these trends were indicative of a deterioration of oxygen conditions in the profundal. Indeed, low oxygen concentrations persisted longer in 1992 than in 1991 (Ph. Vioget, pers. com.), but a detailed analysis of the oxygen trend in the profundal was not available.

DISCUSSION

In Lake Joux (Switzerland), the abundance of *Oscillatoria rubescens* presented no significant downward trend between 1980 and 1992 (Fig. 1), even after phosphorus concentrations began to decrease in 1986 (VIOGET 1991). As in Lake Joux, dense populations of *Oscillatoria* persist in other lakes after the decline of phosphorus (STEINBERG & HARTMANN 1988). According to data reviewed by these authors, Lake Joux presents some of the characteristics which facilitate the persistence of *Oscillatoria*. Firstly, the lake is relatively shallow (mean depth: 20 m): therefore, *Oscillatoria* can easily recolonize the water column from the sediment. Secondly, the lake freezes during three months each winter: therefore *Oscillatoria*, which is able to maintain dense populations under the ice, is abundant enough in the early spring to shade and thus to outcompete the other species. But, whatever are the reasons why *Oscillatoria* persists (see LANG & LANG 1986), this persistence affects zoobenthos.

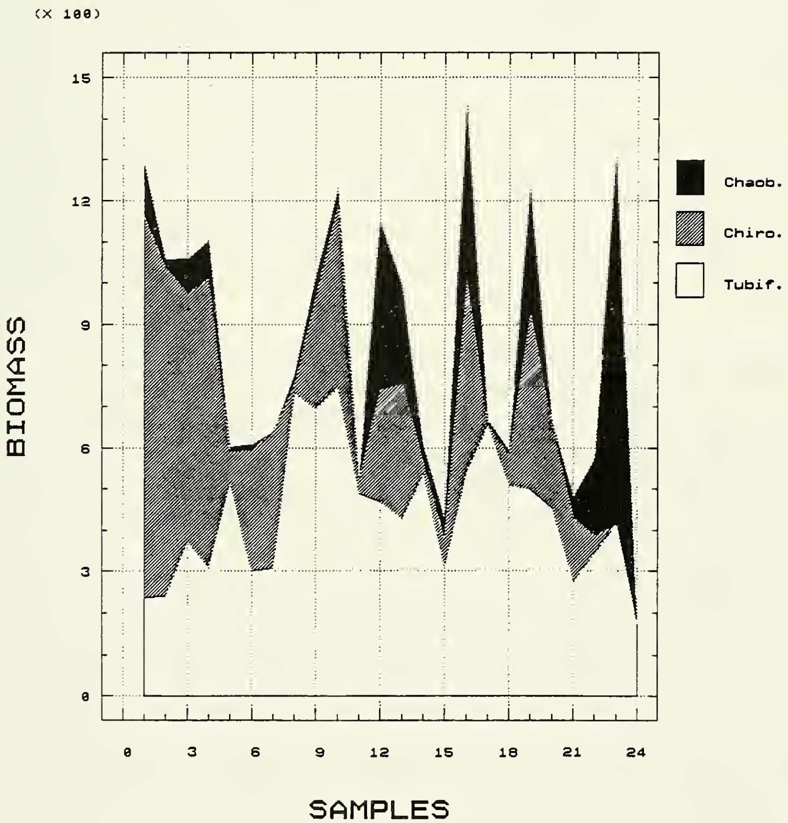

FIG. 2

Variations of cumulated biomass (mg ·160 cm^{-2}) of *Chaoborus* (Chaob.), chironomids (Chiro.), and tubificids (Tubif.) from 1985 (samples 1 - 3) to 1992 (samples 22 - 24) in Lake Joux.

Zoobenthos is affected directly by the variations of organic sedimentation derived from phytoplankton (LANG & HUTTER 1981). Zoobenthos responds initially to the amount of organic sedimentation, but also to its composition (HUTTER & LANG 1981). Organic sedimentation is high in Lake Joux (240 g $C \cdot m^{-2} \cdot yr^{-1}$) and *Oscillatoria* is very abundant in the sedimented matter (LANG & LANG 1986). Oxygen uptake by the sediment is very high if the sedimented matter consists mainly of *Oscillatoria* threads (HUTTER & LANG 1981). Therefore the persistence of *Oscillatoria* prevents the increase of oxygen concentrations in the profundal.

As a consequence, zoobenthos of Lake Joux consists, at least in the profundal, only of tolerant species adapted to the severe anoxia of eutrophic lakes (LANG & LANG 1986). At a depth of 25 m, the trends in zoobenthic abundance, recorded between 1985 and 1992 (Tab. 1, Fig. 2), are the same as those associated with the decrease of oxygen concentrations in eutrophic lakes (BRINKHURST 1974). In 1992, the most resistant taxa, i.e. *Chaoborus* and *Tubifex tubifex*, become dominant in zoobenthos as in the deepest area of the very eutrophic Lake Bret (Lang, unpublished data). All these trends suggest that zoobenthos will not recover from eutrophication as long as phytoplankton is dominated by *Oscillatoria*.

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